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REPORT ON THE GEOLOGY OF THE KOWEN DISTRICT, AUSTRALIAN CAPITAL TERRITORY

by

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REPORT ON THE GEOLOGY OF THE KOWEN DISTRICT, AUSTRALIAN CAPITAL TERRITORY

I. SUMMARY.

The Kowen District occupies the north-eastern portion of the Australian Capital Territory. Watercourses in the area generally flow to the south into the Molonglo River which flows from east to west. The western portion of the district has a youthful topography and is well timbered. In the east the country is more mature and has been cleared for grazing.

The characteristic sedimentary and metamorphic rock types are interbedded sandstones (generally micaceous), shales and tuffs with subordinate slate. Quartzites have been produced locally by the contact effects of igneous intrusions. No conglomerates or limestone were found.

Intrusive igneous rocks are common. The main intrusive is an acidic, medium-grained porphyry with an east-west axis, which occurs principally in the southern half of the district. Outcrops are most irregular and are discontinuous. Intimately associated with it is a diorite which occurs in the porphyry and particularly around its margins. Diorite dykes also occur in the surrounding sediments. To the east several small masses of gabbro and quartz micro-porphyry outcrop.

The main axis of folding is approximately meridional. Strong compression has produced minor folds on larger closed folds, the whole forming the western limb of a synclinorium. Superimposed on this is strong folding on a north-westerly axis.

It appears that thrust faulting in Palaeozoic times left a zone of weakness along which normal faults have developed in late Tertiary or post-Tertiary times. Faulting probably on both the east and the west has left the area as a horst.

The age of the sediments could not be determined owing to the absence of fossils. They are not older than Upper Ordovician or younger than Upper Silurian.

II. INTRODUCTION.

The Kowen District occupies the north-eastern lobe of the A.C.T., to the north-east of Queanbeyan. It is bounded on the south by the Queanbeyan-Goulburn railway, on the west by the Queanbeyan-Gundaroo road and to the north approximately by a divide marked by the trigonometrical stations Poppet, Amungula, Cohen and Bald. The southern continuation of the Lake George escarpments passes just to the east of the district which is slightly more than 30 square miles in area.

The purpose of the survey was to determine the general geology and structure of the Kowen District as part of a planned mapping of the whole of the A.C.T. In addition a search was made for commercial occurrences of rock suitable for use as a building stone.

Apparently no detail work had been done in the area previously. General papers and reports which have been published mention some aspect of the geology of this and adjacent localities. These and other publications, to which reference has been made, are listed in a bibliography at the end of the report.

The Queanbeyan-Bungendore road runs to the south of the western half of the district, entering it at Burbong and then continuing east through the Territory. Owing to the sections exposed in cuttings a considerable amount of work was done on that portion of the road to the west of Burbong.

The field party consisted of J.G. Best, J.A. Mahoney, J.M. Hallinan and the writer. Field work extended over most of January and February, 1949. Mapping was done by use of aerial photographs taken by the Royal Australian Air Force Survey Flight in December, 1944, from a height of 17,000 feet above sea-level. Each print is about 9" x 9" and covers an area of approximately 16 square miles. These prints were carried in the field so that it was generaly a relatively simple matter to locate positions by comparing natural and artificial features on the ground surface with those shown on the air photo. In this way igneous intrusions were plotted direct onto the aerial photographs where possible. Strikes of beds and faults and other suitable information were measured by prismatic compass and dips and pitches were measured by Abney level or clinometer compass. Information was then plotted on a Federal Territory feature map, scale 1" = 20 chains. Contours for section diagrams were obtained from Canberra ordinance map, scale 1" = 1 mile. Bearings given in the text are true bearings.

The aerial photographs available were found to be of little use in interpreting the structure of the sediments or defining the limits of the igneous intrusions.

III. TOPOGRAPHY.

The principal physiographic feature is the Molonglo River. It flows in general from east to west, entering the Territory from the south-east at Burbong, whence it follows a rather meandering course immediately north of the railway and leaves the district at the south-west corner. Consequently the area is drained for the most part to the south. A divide, with a maximum height of just over 3,000 feet, forms the northern boundary.

A fault scarp lies to the east of the Queanbeyan-Gundaroo road at a distance of from 200 to 1,000 yards. It has an average strike of about north 10° east, the downthrown block being to the west. Similarly the north-south Lake George fault, with the eastern block downthrown, flanks the east of the distric so that the area between the two faults is left as a horst. The faulting was very slow and took place in geologically recent times (it may be still continuing) so that the Molonglo River, which antedates the faulting, was able to maintain its course by erosion of its bed, giving rise to deeply entrenched meanders. (For a discussion of this subject see T.G. Taylor (1907)). In the west the river has had to cut through hard quartzites so that its valley, the cutting of which was probably aided by headward erosion, is deep and youthful in profile. The valley is more than 300 feet deep in this part. In the central and eastern parts of the district the topography is mature, largely due to the softer sediments - generally micaceous sandstones and shales - which were rapidly eroded. Subsidiary watercourses in the west, which have deeply dissected the area, generally follow the strike of the sediments. In three places it was noticed that the streams have made their valleys along small dioritic dykes.

In the vicinity of larger igneous intrusives, watercourses commonly follow the contact between the porphyry and sediments so that porphyry is found on the flanks of hills and less commonly on the crests. In the east, differential erosion of soft shales and sandstones on the one hand and harder quartzites and other indurated sediments on the other, has produced north-south ridges which have served to accentuate the Lake George fault scarp north of the Queanbeyan-Bungendore road.

Deep soil covers the lower levels of the eastern and central parts of the district but this soil has been cut through by recent erosion gullies, apparently due to deforestation and perhaps assisted by over-stocking. In some places the gullies have failed to expose bedrock at a depth of 10 feet. The gully walls consist of soil with layers of angular fragments showing that the alluvium and hill wash were carried down by sudden freshets much as is being done today under active erosion conditions.

IV. DESCRIPTIVE GEOLOGY.

A. Sediments and Metamorphic Rocks.

The sedimentary rocks of the district are thinly interbedded, showing rapidly fluctuating conditions of deposition. The thickest beds observed were some sandstones and quartzites which reach a thickness of about 6 feet but these are exceptional, the average thickness being of the order of one foot or less. Many beds are only a few inches thick. The total thickness of sedimentation represented by the rocks of the district, although it cannot be estimated owing to the complexity of folding, must be considerable. There is no fossil evidence of the environment of deposition but it is probably marine. Some graded beds were observed, as for example in a railway cutting just east of Burbong, so that deposition sufficiently near shore to permit influence by weather conditions is indicated. However, the sediments are generally fine, and conglomerates and coarse sandstone are absent. No limestone was found in the district. Current bedding was not seen.

A feature of the sediments is the prevalence of acid tuffs. These occur at intervals right across the area from the first road and rail cuttings in the west to an extensive group of tuffs which are exposed in the railway cutting to the east of the tunnel on the eastern boundary of the Territory. Extensive outcrops occur also in the large loop of the Molonglo, on the railway 1½ miles east of Burbong and again about two miles west of the tunnel mentioned above. In addition numerous other beds of tuff were recorded. Many of these were given the field name of "spotted sandstone" but petrological examination (see Appendix - Specimen No. 9) shows that they are more or less pure tuffs with large crystals of quartz and felspar. Many sandstones show slight spotting so it is probable these are tuffaceous sandstones. As no large scale repetition of beds could be established it would appear that frequent eruptions of pyroclastic material took place throughout the whole of the geological time represented by the rocks of the area. A finely agglomeratic tuff occurs in the west (see Appendix - Specimen No. 24) but no lavas were found. The tuffs were apparently deposited under water. This is indicated by the admixture of sand and clay in some beds and by the thin interbedding of the tuffs with sandstone and shale. The tuffs are shown by microscopic examination to be very acid in composition. Quartz is the chief mineral and the dominant felspar is andesine. Names suggested are quartz tuff (Specimen No. 36), quartz (dacite) tuff (Specimen Nos. 34 and 35), quartz dacite tuff (Specimens Nos. 9 and 24) and dacite tuff (Specimen No. 8).

Perhaps the predominant sedimentary type is micaceous sandstone, which can be found in almost any part of the district. The mica content varies considerably; so does the grain size and character of the mica-bearing sediments. Shales, very fine sandstones and medium grained sandstones have all been found to contain mica flakes.. These flakes lie in the bedding plane and are therefore not of secondary mica. Fissile, flaggy and massive sandstones can all be seen in the district, often interbedded, though the apparently fissile nature of some sandstone outcrops is undoubtedly due to fracture cleavage at folds. Non-micaceous sandstones also occur. Their best development is in the east where certain distinctive sandstones can be recognised.

Shale is a common rock type. Generally it occurs thinly interbedded with sandstone or tuff. In the vicinity of the most easterly fault shown on the map (outside A.C.T.) thinly bedded shales occur alone. The shales range in composition from true shales to sandy shales, grading into argillaceous sandstones. There is also considerable variation in the degree of development of cleavage so that true shales, shales with coarse cleavage developed near the axes of folds and slates can all be found.

Slates are found fairly commonly throughout the district, but in most places they occur in minor amounts. Locally slates may become predominant, as for example in a line of beds which strike from the northern boundary on an average bearing of south 20° west to pass near the Kowen homestead and Relic Trig. station. Well-developed slate occurs along the eastern boundary between two outcrops of gabbro. Thin beds of unctuous slate are to be seen in numerous places west of Burbong and elsewhere. These appear to have been derived from tuffaceous material. Similar slates in a railway cutting just east of Dairy Station Creek have an almost phyllitic texture. This texture is perhaps better developed along the strike of the beds to the north.

Quartzite found in the area is essentially the product of contact metamorphism. It is developed locally at the contact of each of the four types of igneous rock - porphyry, diorite, gabbro and quartz micro-porphyry - with sandstones, though this is by no means always the case (see further Section IVB "Intrusive Igneous Rocks"). However, the best development of quartzite is in the bed of the Molonglo and more particularly in the large loop to the west of Burbong. These quartzites extend west across the strike some two miles to a point half a mile east of the mouth of the defile, but by no means continuously. They are derived from various types of sandstone and have been silicified to different degrees. They are shot through with numerous tiny veinlets of quartz. The best developed are hard dark grey quartzites. Thinly interbedded with the quartzites are indurated slates.

In railway cuttings just to the south of the river and 100 feet higher than it the degree and extent of silicification is less and to the south and north of the river it dies out. From this it may be inferred that there is an igneous mass at no great depth below the level of the stream bed.

Some beds which appear superficially to be quartzite have been found on breaking with a hammer to be silicified at the surface only and to be sandstone beneath.

A small occurrence of a green schistose rock has been observed on the Lake George scarp, in contact with one of the outcrops of gabbro. Examination of a thin section suggests the name quartz chlorite schist (see Appendix - Specimen Nos. 25, 25A). Apparently it was formed by the introduction of quartz and other minerals (?) into what was probably an impure tuff.

In a small creek just north of the railway 1½ miles west of Burbong some light and dark grey banded tuffaceous slates contain a small amount of black chert. This is the only chert found and it is not typical of the lithology of the district.

To sum up, the characteristic sedimentary and metamorphic rock types of the district are thinly interbedded micaceous sandstones, shales and tuff with subordinate slate. Quartzites have been produced locally by the contact effects of igneous intrusions.

B. Intrusive Igneous Rocks.

The main igneous intrusive occurs along an east-west axis which passes to the north of Burbong. Its outcrops are most irregular giving small isolated outcrops and other larger bodies which include bodies of country rock. Other portions extend as irregular dyke-like bodies of width from 30 feet up to several hundred feet. These outcrops almost invariably transgress the bedding. The few isolated sills appear to be local only. The irregular pattern gives the impression that the outcrops represent apophyses from a magma which lay at no very great depth below the present surface. The east-west arrangement of the intrusion suggests a structural weakness along this line (see Section IV C - "Structure"). The various parts of the intrusive differ greatly in texture and composition and more particularly in the contact effects. The main body of the rock is acidic, porphyritic and medium grained. Sections of specimens collected from within the large loop of the Molonglo and from Sparrow Trig. station have been described as granophyric porphyritic adamellite and sheared granodiorite porphyry respectively (see Appendix - Specimens Nos. 31 and 23. See also Specimen No. 55). The latter is a marginal phase. Since the outcrops are generally hypabyssal rather than plutonic, for convenience the rock type will be called porphyry in the text. The shearing, where it occurs, is confined to a narrow zone near the contact and the rock in such a case is generally more acid than elsewhere. The contact, however, is not always sheared. It is in many places occupied by a more basic phase which cuts through the main mass of porphyry and in places constitutes an appreciable proportion of the igneous body. This phase has the composition of a diorite (see Appendix - Specimen No. 32). It is generally fine to medium and even grained. The contact between the diorite and porphyry is usually well-defined though gradations do occur with the production of hybrid types. A sufficient number of sections have not been studied to permit a discussion of this aspect. A feature of the diorites is the high proportion of epidote and chlorite present. These two minerals are practically the only dark minerals.

It would appear that the magma had started to crystallize when diastrophic forces injected it into its present position in a semi-molten state and under high pressure. This produced a sheared margin and shattered the country rock in the immediate vicinity. The later diorite came up through the emplaced porphyry, occupied the shattered margin and in places penetrated far into the country rock. Evidence of this is given by the existence of dykes of diorite and quartz diorite (see Appendix - Specimens Nos. 1, 2, 2A) similar to the diorite associated with the porphyry, in the north-west of the district, some distance from the nearest observed outcrop of porphyry. The exposures of what is presumably diorite in the railway cuttings are invariably very strongly weathered leaving only a green crumbly rock quite unsuitable for sectioning.

Where the diorite does not lie between the porphyry and the country rock it is almost impossible to find the contact due to soil cover. This could be taken to indicate the low temperature forcible injection of the porphyry with the shattering of the intruded sediments and negligible thermal metamorphic effects. In this connection too the preference of watercourses for contact zones may be cited.

On the other hand there are localities where quartzites have been developed in the vicinity of the porphyry and this can only be attributed to the contact metamorphism. The extensive development of quartzites in the Molonglo River has already been explained by the presence of an igneous body below. Why the eastern portion of the body of porphyry should break through in numerous apophyses and dykes with comparatively little silicification of the country rock, while in the west quartzitisation is extensive and outcrops less extensive, is not obvious. Undoubtedly other outcrops of porphyry and diorite remain to be located in the latter area, whose greater ruggedness and timber cover gave poorer access. The line of porphyry shown west of the Molonglo loop is the result of observations on two traverses. The outlines are not exact but give an idea of the position and size of the occurrences. Outcrops are essentially discontinuous though generally in line. They are similar to outcrops of the same dimensions further east; they have in part sheared acid margins and in part marginal diorite. An examination of aerial photographs suggests there may be another line of porphyry farther north but that the country south of the line of outcrops and north of the river is free from igneous rocks since contours appear to be determined by bedding.

With regard to the degree of silicification of the sediments, it was found that contact effects of the outcrops in the west are no greater than in the east. The quartzite is only exposed in quantity where the river has cut down some distance - not necessarily in the vicinity of outcrops of igneous rocks.

Xenoliths are characteristically absent from the porphyry and diorite. Only one locality yielded any at all. This was in porphyry near the contact in a railway cutting three miles east of Burbong. The xenoliths are small - less than an inch across. Probably other marginal zones contain xenoliths but they are hidden by soil. Pegmatitic and aplitic phases are absent and jointing is not pronounced. A slight degree of mineralization of the diorite and porphyry is indicated by the discovery of small disseminated crystals of pyrrhotite and pyrite in several specimens (see Appendix - Specimens Nos. 1 and 31, also in the dyke rock to the north of the loop in the Molonglo).

Of the dykes and sills from which specimens of rocks were collected and sectioned, a four foot sill (locally at least) cutting the railway 180 feet to the east of the Burbong bridge (see Appendix - Specimen No. 7) alone showed a different petrological type from the main diorite mass. The rock in this sill is a typical dolerite. It has dolerite texture and contains plagioclase, orthoclase and augite with subordinate epidote. Quartz is absent. The plagioclase is, however, andesine. The dyke is closely jointed.

Along the line of the Lake George scarp there are several outcrops of gabbro (see Appendix - Specimen No. 26). The rock is medium to coarse and even grained - a typical plutonic rock. It has intruded the sediments, converting adjacent sandstone to quartzite. There is also a small fine-grained phase in one place. Thin section examination (see Appendix - Specimen No. 42) shows that it is a dolerite which is closely related to the gabbro. The most abundant ferromagnesian mineral is tremolite as in the gabbro. However the plagioclase is andesine; this provides a possible link with the dolerite sill near Burbong. Further it contains disseminated pyrrhotite in similar manner and quantity to the dioritic dykes.

Just to the east of this fine grained phase and in contact with the gabbro there is a finely puckered schistose rock (referred to in the previous section) which was probably originally an impure tuff. As it was only found here and farther north as a floater adjacent to the gabbro it is presumably due to the action of the gabbro and together with the quartzite affords evidence that the gabbro does not antedate the sediments.

A short distance further west several irregular bodies of a quartzo-felspathic rock outcrop. The rock is markedly porphyritic with phenocrysts largely of quartz and a very fine groundmass. The name quartz micro-porphyry is suggested (see Appendix - Specimens Nos. 27A, B). The outcrops are surrounded by aureoles of quartzite which are shot through with small veins of quartz.

Sufficient evidence was not obtained to ascertain the relationships existing between the various igneous rock types but there are certain similarities which point to a fairly close connection between all or most of them - the tremolite derived from augite in the gabbro and dolerite in the west; the occurrence of andesine rather than labradorite in the two intrusions of dolerite, the intimate association of porphyry and diorite and the presence of pyrrhotite in specimens of porphyry, diorite and dolerite. However the presence of pyrite and pyrrhotite could be explained as due to a later minalization.

C. Structure.

I. Folding.

(a) Folding of the sediments is very complex. It involves at least two periods of crustal shortening, the later having been superimposed across the strike of the first folding and showing on the surface as pitch. Perhaps the clearest method of treatment would be to set out the party's observations and then to give the writer's interpretation of them.

Railway and road cuttings and stream valleys almost without exception show close and irregular folding. The amplitude and wavelength of the folds varies from two feet to about 60 feet and even more. The folds are generally closed - or almost so - but occasionally open folds and even small scale monoclines occur. The common characteristic is irregularity. These regions were consequently of little value for getting representative dips. However, between the areas of close folding short intervals with reasonably constant dips enabled us to form a regional picture. Small scale thrust faults accompany the folding in places, for example, in the road cutting below the Lookout a number of thrust faults with displacements to the order of two feet occur. Similar thrust faults may be seen along the strike of the sediments on the railway.

Strike is rather variable but the average is about north 20° east. The general strike in the west of the area is more easterly than in the east. In tracing strike lines across the district the party found that while the strike maintained a fairly constant direction variations up to 50° were encountered. Owing to the lack of good marker beds we could not be certain we were following one bed throughout, although the general strike was followed. It is probable that in between outcrops we sometimes changed from one bed to a similar one or on to a repetition of the same bed, due to minor folds. Owing to the shattering and development of fracture cleavage in competent beds the location of any abrupt change in the direction of strike was most difficult.

Dip shows a fairly constant change across the strike from 30°-50°E just east of the western scarp to vertical about two miles west of the eastern boundary of the district and 50° west one mile east of this boundary. There are numerous exceptions to this, undoubtedly where the western limbs of more open anticlines are exposed. This is particularly noticeable in the east, indicating that folding is more open there than in the west. For example, a fairly large simple fold just east of the postulated probable fault line to the west of the Lake George fault has its limbs dipping west 63° and east 77°.

Measurement of the inclination of axial planes showed a similar though less pronounced trend. Readings obtained from west to east run 66° east, 24° east, 65° east, 60° east, 74° east, 66° east and 83° west. As these measurements were made on small irregular folds the anomalies are to be expected.

Very few dips of cleavage planes were obtained but those that were lay between 60° east and 65° east.

Evidence for the repetition of beds was hard to get as there are few beds which are sufficiently distinctive to be readily recognised. Chief use had to be made of the relative abundance of slates and sandstones or shales and tuffs, etc., and as exposures were not continuous this method was not very satisfactory. The rule using the acute angle between trace of cleavage and bedding in vertical sections was applied where possible and this enabled the positions of some of the larger folds to be determined but its applicability was very restricted. The few graded beds also proved of little use.

Most of the small folds seen have some element of pitch so that a fairly complete picture of the variations in pitch was built up, at least in the south. The difficulty often lay, not in getting a pitch reading, but in choosing a representative one in certain localities where they showed astonishing variation, as can be seen from the map. In one place the pitch along the crest of a small anticline changes from zero to 30°N in three yards.

(b) Interpretation. The rather consistent dip, taken in conjunction with the close folding indicates that isoclinal folding, or a near approach to it, persists throughout the area though a tendency towards more open folding exists in the east. The alternation of close folding with less crumpled exposures in vertical sections and the repetition of beds indicates that larger folds must be present in addition to the minor folding.

However, no large group of beds was observed to be repeated more than twice. Further the general dip of the beddings and axial planes is to the east, becoming more vertical and finally westerly in the east. These two facts can be explained as due to the area being occupied by the western limb of a synclinorium with the base of the structure near the eastern boundary. This agrees with Garetty's conclusion that the area to the east of Lake George lies on the eastern limb of a synclinorium, whose axis is approximately meridional (M. D. Garretty, 1936(a)). The steepening of dips near the Gundaroo Road suggests that the crest of an anticlinorium may be not far to the west of that road.

At first glance the pitch appears to be erratic and not to vary according to any definite pattern. However, closer examination shows that lines with a fairly constant bearing can be traced through the points where the pitch changes from north to south to give the pattern shown on the map. Apparently the pitch represents superimposed folding along axes which run approximately north-west. Dips and strikes which represent folding in this direction have been mapped in Silurian strata in the Canberra area by G. McInnes and B. Flinter. Two folds east of Burbong appear to die out to the north. The pitch, being measured along the strike of the north-south folding, does not represent the true dip of the superimposed folds but some angle less than the true dip. The cross-folding is therefore strong. The wavelength of each fold is to the order of 2,000 yards.

The superimposed folding is responsible for the variation in the direction of strike along the strike line. Completely closed elongated outcrops of beds are to be expected but we were not successful in tracing any such closure due to the complexity of folding with the consequent fracturing of beds and to the non-continuity of outcrops. However, several zones of very variable strike, with high pitch (which showed the minor folds in plan on the surface) suggest that the beds do double back as the postulated structure requires.

The marked east-west axis of the major igneous intrusion calls for some explanation in terms of structure but we did not find sufficient evidence in the area to attempt to solve the problem. Attention should be drawn, however, to the fact that the pitch is generally steeper across the south of the area than elsewhere. Probably the answer is to be found by a broader regional approach. As no work has been done immediately to the south of the Kowen District it is not known just what the shape, extent and nature of any intrusions there may be. Possibly work there would reveal a very different overall outline to what we have at present.

2. Faulting.

An examination of a contour map or, better still, of aerial photographs under a stereoscope shows a well-defined scarp just east of the Gundaroo Road which trends generally north 10° east. Its straightness immediately suggests a fault scarp, so that one of the first tasks of this party was to seek field evidence to support this suggestion.

Brecciation was found in limited zones in the Molonglo valley at the mouth of the defile, along the Kowen homestead road where it climbs the scarp and again possibly in a creek in the north. In a railway cutting near the brecciation in the Molonglo valley there is a strong zone of weathering which undoubtedly represents a fracture zone. Farther east on the railway a zone of strongly contorted and shattered beds marks the position of a subsidiary fault. On the Bungendore road brecciation is present. A continuation of this fault line, which lies farther east again of the main scarp, is to be found in a stream bed 100 yards north of the road; here the rocks are somewhat contorted. The zones of faulting are all at a high angle but are too ill-defined to assign a definite dip to the faults. The degree of brecciation and contortion appears rather inadequate for the size of the scarp (which must originally have been upwards of 500 feet) but this is probably due to the formation of the scarp by several close parallel faults.

To the east of the Territory lies the much discussed Lake George escarpment (see Taylor 1907 and Garretty 1936(b)). Taylor contends that the scarp is due to quite recent faulting which has let down the eastern block, beheading all rivers crossing the fault line, with the exception of the Molonglo which succeeded in degrading its bed at a rate sufficient to maintain its course, thereby producing the Molonglo defile four miles south of the eastern boundary of the Kowen District. He estimates the maximum throw of the fault at about 400 feet. Evidence he cites includes strong contortion of beds in the Molonglo defile and the presence of boulders and river gravels in Geary's Gap, west of Lake George. He regards Geary's Gap as a water gap, indicating a beheaded river whose tributaries now remain as feeders of Lake George. The direction of flow of these "betrunked" streams is towards the gap. He considers there has never been an outlet from the lake to the north.

Garretty, on the other hand, maintains that the scarp is due to differential erosion and that Lake George was formed by a downwarping which destroyed a north-flowing stream. He points out that there is only a narrow belt of low-lying country to the east of the scarp. This could have been the old river valley. The river gravels in Geary's Gap, he thinks, may be a remnant of an older drainage system. In his opinion any faulting of Tertiary or Recent age would have produced brecciation rather than the crumpling of strata. He does not exclude the possibility of Palaeozoic faulting.

Examination of aerial photographs of an area extending from west of Bungendore to just north of the Molonglo defile reveals three lines of escarpment, all striking almost due north-south. The westernmost line is that to the west of Bungendore. It dies out 1½ miles to the north of the Territorial boundary, to be replaced by the scarp which passes along the eastern boundary of the District. The line of this scarp is about one quarter of a mile east of the first-mentioned one. The scarp ends quite abruptly at the Queanbeyan-Bungendore road. The third line is about a half-mile east again. It continues to the south from the railway.

In cuttings on the railway approximately in line with the first two scarps there are zones of crumpling which indicate stressing, though whether actual relative movement has occurred is doubtful. A definite fault on the line of the easternmost scarp is well exposed in a railway cutting as a zone several feet thick of intense weathering in which the material is structureless except for thick bands of limonite. On either side the sediments, which are shale on the east and shale and quartzite on the west, are intensely crumpled and puckered. The quartzite strata have been broken into fragments. On the east this distortion persists for at least two hundred yards; drag folds occur adjacent to the fault showing the east block has moved down relative to the west block. The fault at this point strikes two degrees west of north; the dip is 65 degrees west. AIr photos show a line on the ground which probably represents a continuation of the fault to the north. The fault presents several conflicting features. The intense crumpling and puckering of the sediments and the west dip of the fault suggest a thrust fault but the angle of dip (65°) is rather high. However as the downthrown side of the scarp further south is to the east, if the scarp has been produced by a tension fault the west dip is anomalous.

Considering the three scarps, the following facts point toward pre-Tertiary (probably Palaeozoic) overthrust faulting, or at least a line of structural weakness, which would undoubtedly be related to the close folding of the sediments :-

The intense puckering and crumpling of sediments.

The suggestion of an old fault line north of the Bungendore road, in line with the definite fault. Here there is no appreciable topographic change.

North south trend of the outcrops of gabbro and quartz microporphyry.

The existence of the mineralized Captain's Flat shear zone, which is undoubtedly of pre-Tertiary age, on the general line of the scarps, to the south.

Little further evidence for Tertiary or post-Tertiary normal faulting has been produced by this investigation. Nevertheless it is considered that since faulting in the vicinity of the line of the escarpment has certainly taken place at some time and faulting in the west of the District has produced a somewhat comparable scarp that the formation of the Lake George scarp lines by faulting may reasonably be inferred. The region between the two fault zones in this case then becomes a horst.

The probable fault just east of Burbong has been deduced from a zone of slight brecciation lying at a high angle to the east. It is undoubtedly only local.

The tension faulting in the area is apparently a product of the differential warping associated with the late Tertiary or Early Pleistocene Koscuisko uplift.

V. AGE OF THE SEDIMENTS.

No fossils were found in the Kowen District despite a search by B. W. Vitnell lasting about ten days and close attention to the matter by this party. However, some strata appear favourable to the preservation of fossil remains and probably an intensive search in the less contorted portions would produce results. Possible fossil remains were found by Dr. N.H. Fisher in tuffs in a railway cutting a short distance to the east of the eastern boundary of the Territory. They are quite indeterminable.

In the absence of fossils recourse must be had to lithology and structure. However, these produce conflicting evidence. The strata in the west of the District bear a marked resemblance to those of the Tidbinbilla formation near Kambah Pool 9 miles south-west of Canberra. The similarity applies both to the degree and complexity of folding and pitching and to rock type, with the exception that no tuffs have been reported in the Tidbinbilla formation (which on the present known evidence appears to be Upper Ordovician image) and slates appear to be too prominent.

A close comparison can also be drawn with portions of the Mount Fairy series to the east of Lake George, described by Garretty (1). Part of this formation contains shales, sandy shales, grits and occasional tuffs (described by Garretty as quartz tuffs); these could be analogous to the tuffs of the Kowen District. (See Appendix - Specimens Nos. 8, 9, 24, 34, 35 and 36). The shales have not yet yielded fossils. Furthermore, the structure is similar - isoclinal folding and variable pitch - and the beds form the eastern limb of a synclinorium. The Mount Fairy series has been dated by Garretty as "probably Upper Silurian in age, though there is a possibility that it is, in part, of Lower Silurian age" mainly on the evidence of fossils found in limestones in the eastern portion of the formation.

Little help is forthcoming from an examination of the ages of surrounding areas, so far as they are known. There is a belt of Upper Ordovician faulted on the western side against Silurian to the west of Queanbeyan. The age of the Ordovician has been well established by graptolites from several localities. However, these strata bear no close lithological resemblance to any of the Kowen District rocks. No work has been done on the area to the north of the Kowen District or immediately to the south but at a point about two miles south of its western end known Silurian rocks exist. The faulting on the west would not have a significant effect as it is of such recent age and the beds have such a high dip. However, in the east probable Palaeozoic faulting may have produced an unconformity.

No factual contribution can be made, then, to knowledge of the age of the sediments of the District. That the age is between Upper Ordovician and Upper Silurian cannot be doubted, but a closer assignment of age cannot be justified.

VI. ECONOMIC PROSPECTS

Mineralization in the District is negligible and the prospects of finding metallic minerals in economic quantity is remote. No record could be found of the occurrence of gold, though small quartz reefs are common, and it is considered that there is little possibility of other metallic minerals being found in quantity.

In considering the suitability of rocks as building stone or as a source of brickmaking material, aggregate or road material, where large quantities are generally necessary to constitute an economic deposit, the factors of reserves, accessibility and markets become of prime importance. On these points most of the possible workable deposits in the Kowen District must be dismissed.

Building Stone. There are occurrences of sandstone which would probably provide suitable building material, being flaggy and therefore readily workable, reasonably pure and of pleasing colour but such occurrences of straight, unwarped stone are generally too small and too inaccessible to be economically worked and transported to Canberra, the nearest potential market of any size. The quartzites are usually too massive and sombre in colour. Accessibility will be improved by the construction of a road to Bungendore north of the Molonglo which was being surveyed while field work was in progress.

Brick Shale. The shales which occur in the area are generally thinly interbedded with sandstone and are themselves often sandy so it is doubtful whether they could be used for brickmaking.

Sand and Aggregate. Deposits of sand and river gravel are not extensive. They are confined to the Molonglo valley west of Burbong and are not well sorted. They generally contain shaly material and therefore are unsuitable as a source of building sand or aggregate.

Road Materials. Suitable sediments for local road making are available almost anywhere in the District. Probably the igneous rocks would also be found on investigation to be suitable for road metal.

VII. ACKNOWLEDGMENTS.

I wish to acknowledge and express my appreciation of the advice given, particularly on structural problems, and interest taken in the work on the Kowen District by Mr. L. C. Noakes. Thanks is also due to Mr. W. Dallwitz for his assistance in the determination of the petrology of the specimens sectioned and to Mr. J.J.E. Glover for reading and criticising this report. Other members of the staff of the Bureau have been helpful and generous in their advice and suggestions and all such assistance is gratefully acknowledged.

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APPENDIX.

DESCRIPTIONS OF SECTIONS OF HAND SPECIMENS OF ROCKS COLLECTED KOWEN DISTRICT, A.C.T. JANUARY - FEBRUARY, 1949.

SPECIMEN NO. 1:

Locality:

Hill 300 yards N.W. of Kowen homestead (McInnes' house) in pine plantation. Dyke 20 yards across.

Description:

Hand Specimen: Massive, rather finegrained, dark grey-green in colour with fine particles of yellow and pink-brown sulphides (pyrrhotite and pyrite ?). Purple stains on weathered surfaces.

Thin Section: Holocrystalline, sub-equigranular, hypidiomorphic. No preferred orientation direction. Light colour/ed minerals appear to be slightly in excess of the dark minerals. Weathering has converted most of the ferromagnesians to chlorite and has partially kaolinized the felspars.

The felspars consist of andesine and orthoclase. Crystals are small (less than 0.25 mm.), subhedral and kaolinized particularly the orthoclase. Plagioclase is dominant. Quartz is fairly common as a late stage mineral. It shows strain shadows.

The dominant dark mineral is epidote which is brown and very irregular in outline. Chlorite, apparently derived from hornblende is also prominent, making up the bulk of the remaining dark minerals. Magnetite is distributed freely throughout in euhedral crystals. Irregular black opaque masses may be ilmenite, which has been leucoxenized in part. Sulphides are not present in the slide. Accessory apetite occurs in needles set in the quartz and felspar.

The rock may be described as a finegrained Quartz Diorite.

SPECIMEN NO. 2:

Locality:

Dyke in north-west of district - southernmost of the dykes shown in that locality on the map.

Description:

Hand Specimen. The rock is similar in appearance to Specimen No. 1 but is slightly coarser grained. It is a dark grey-green even-grained rock.

Thin Section. The specimen has been strongly weathered It is medium grained, with crystals up to 4 mm. long, sub-equigranular, holocrystalline. Crystal boundaries are generally irregular due to alteration. An irregular alignment of crystals in strings is noticeable. This is particularly the case with chlorite. Chief minerals are felspar, chlorite (derived from hornblende) quartz, epidote and magnetite. Accessory apatite is also present.

Both plagioclase and orthoclase are present; the former, probably as andesine, is dominant. Crystals rarely exceed 1 mm. in length. Quartz constitutes perhaps 5 per cent of the total. Crystals average 0.5 mm., are anhedral and display strain shadows.

Chlorite crystals sometimes reach the length of 4 mm. but this is not common. Partially altered hornblende can be seen. Epidote is not very plentiful.

In the groundmass fine granophyric intergrowths of felspar and quartz are common. The felspar is untwinned; it may be orthoclase.

Rock has been called medium-grained quartz diorite.

SPECIMEN NO. 2A.

Locality:

Margin of dyke from which Specimen No. 2 was collected.

Description:

Hand specimen. The rock is strongly weathered, giving it a black appearance, speckled with the white of altered felspar. Grain size is small. It has a slight lineation (parallel to the wall of the dyke).

Thin Section. Mineral content is much as in Specimen No. 2 but quartz is less prominent. Lineation is no more pronounced in thin section than in No. 2. Its appearance in the hand specimen is probably a function of weathering. The specimen may be described as medium grained diorite.

SPECIMEN NO. 7.

Locality. A dyke in a cutting on the Queanbeyan-Bungendore railway, 60 yards east of the bridge over the Molonglo River, just east of Burbong railway station.

Description:

Hand Specimen. A fine even-grained grey rock with faint greenish tinge. Grains or crystals are generally not readily distinguishable.

Thin Section. Holocrystalline, equigranular, hypidiomorphic; dominant mineral is felspar which is lathlike in form, the laths rarely exceeding 1 mm. in length. There is considerable augite present. It is colourless, is somewhat fragmentary and cleavage is poorly developed. Epidote is also present. The felspars are andesine and orthoclase, the former being strongly predominant. They have been strongly kaolinized in part. Quartz is absent.

Name of rock is Dolerite.

SPECIMEN NO. 8.

Locality:

From east end of cutting on Queanbeyan-Bungendore railway about half a mile east of Burbong.

Description:

Hand Specimen. It is a grey-green rock with a slight sheen. It has a somewhat contorted bedded appearance and is cut by veinlets of quartz. It occurs as a bed between normal sediments.

Thin Section. The rock is inequigranular with irregular fragments of quartz of an average length of 0.5 mm. and small subordinate irregular fragments of andesine and muscovite. These crystals are set in a fine matrix of felspar, chlorite and sericite. The matrix is bedded and the larger crystals have their longer axes more or less along the plane of bedding. The slightly schistose appearance of the hand specimen appears to be due to the presence of the larger grains in a tuffaceous groundmass. There is no evidence of recrystallization.

The acid nature of the rock is apparent and it can be described as a Dacite tuff.

SPECIMEN NO. 9.

Locality:

From east end of cutting on Queanbeyan-Bungendore railway, approximately 1½ miles east of Burbong.

Description.

Hand Specimen. The hand specimen is light brown in colour with small grains of quartz and white felspar, giving a "spotted" appearance. It is slightly stratified; obviously a tuff or tuffaceous sandstone.

Thin Section. Nearly 50 per cent of the section consists of angular sub-equidimensional fragments of quartz which average less than 0.5 mm. across. Similar fragments of andesine (?) are present but these comprise only a small proportion of the rock total.

The matrix is generally very fine. It contains quartz, felspar, muscovite and perhaps sericite.

Owing to the abundance of quartz the name Quartz Dacite Tuff is suggested.

SPECIMEN NO. 14.

Locality.

Cutting on Bungendore road, 50 yards east of east boundary of thedistrict.

Description.

Hand Specimen. The hand specimen shows a very fine soft powdery light brown sedimentary rock. It appears to be an unbedded fine mudstone or shale.

Thin Section. The grainsize of this specimen is such that determination of minerals is difficult. Sericite and quartz are the only minerals that can be identified. The sericite suggests that low grade metamorphism has taken place. Limonite occurs in strings and pockets along either the bedding or incipient shear planes.

The rock is a slightly sheared very fine sandy shale.

SPECIMEN NO. 16.

Locality.

Railway cutting 150 yards west of the tunnel on the eastern boundary of the Territory.

Description.

Hand Specimen. Rather fine, light brown in colour. Has a "flaky" appearance indicating shearing. Appears to be a sandstone with very subordinate flakes of mica. The hand specimen has a small veinlet of quartz in it.

Thin Section. It is fine grained (grains generally less than 0.25 mm.). It consists almost exclusively of quartz whose grains are strongly stretched in the one direction. Flakes of muscovite occur in patches arranged in the direction of shearing. Occasional crystals of plagioclase are present. Magnetite and/or ilmenite occur throughout in small crystals.

The rock thus appears to be a sheared sandstone which has been partly recrystallized under shear. The iron oxides are presumably detrital and the mica a recrystallization product of an original argillaceous cement. However the mica and felspar may indicate that the sandstone was tuffaceous.

SPECIMEN NO. 23.

Locality.

On the margin of the porphyry, Trig. Station Sparrow - 2¾ miles east of Burbong.

Description.

Hand specimen. It is a light coloured porphyritic rock with medium sized quartz grains and a fine felspathic ground mass. Some subordinate dark minerals are also present. The quartz grains are aligned and have been strongly stretched (parallel to the plane of the contact).

Thin Section. The section is holocrystalline and very inequigranular. Phenocrysts are generally elongated with the long axes arranged in the one direction. Quartz is the commonest mineral, felspar occupying a lesser place and epidote and chlorite a minor one. Phenocrysts are up to 4mm. in length the average length being about 1.5 mm. The quartz is generally rounded and slightly embayed. It is often fractured and displays pronounced strain shadows. The felspar appears to be sodic andesine; there is probably some orthoclase present.

The groundmass is very fine and has the same flow pattern as the phenocrysts. It is made up of felspar - both plagioclase and orthoclase (judged by the presence and absence of twinning in different crystals) - quartz and sericite (?).

The texture indicates that crystallization of the magma had begun when the mass, of which the specimen forms a marginal part, was injected. Rapid cooling near the contact produced a fine groundmass and movement of the semi-solid mass arranged the phenocrysts and groundmass as described. Name given to the rock is sheared granodiorite porphyry.

SPECIMEN NO. 24.

Locality.

From cutting on Queanbeyan-Bungendore road towards the western end of the area - the second most westerly cutting.

Description.

Hand Specimen. It is a very ill-sorted rock, having a finely agglomeratic appearance due to large angular crystals of felspar and quartz set in a fine tuffaceous matrix. The rock has a grey-brown matrix with white felspar and colourless quartz. On one surface the hand specimen has been polished, apparently by movement along the bedding plane.

Thin Section. The section shows the rock to be fragmentary with irregular crystals of quartz and felspar of all sizes from 1 mm. downwards, set closely and at random in the matrix. Quartz is easily the most abundant mineral with felspar next. No specimens of felspar of a size visible in the hand specimen (up to 8 mm.) occur in the slide. The felspars are andesine and probably also orthoclase. The matrix is fine. It is indeterminable because of its size and degree of alteration.

The name given to the specimen is Quartz Dacite tuff.

SPECIMEN NOS. 25, 25A.

Locality.

Collected from a point 150 yards east of the eastern boundary of the District and 200 yards north of the Queanbeyan-Bungendore road.

Description.

Hand Specimen. The rock is green in colour and closely puckered, as can be seen in the hand specimen. It is finely schistose in appearance. Individual grains or crystals are not visible to the naked eye. This rock was found only adjacent to a gabbro (Specimen No. 26) and appears from its field relation to be related to it.

Thin Section. Under the microscope the development of false cleavage can be seen, together with injected quartz veins along the cleavage. Minerals present are quartz, felspar - both plagioclase and orthoclase - chlorite and to a lesser extent biotite and epidote. Little recrystallization seems to have taken place so that the felspar probably indicates the rock was originally a tuff, possibly with clayey material admixed. The rock has now become a quartz chlorite schist.

SPECIMEN NO. 26.

Locality.

150 yards east of eastern boundary of the District and 400 yards north of the Queanbeyan-Bungendore road.

Description.

Hand Specimen. A medium coarse-grained rock, this specimen contains green phenocrysts set in a grey-white ground mass which is apparently largely felspar. It occurs in several rather small outcrops which indicate it to be an intrusive rock. Texture proclaims it to be plutonic.

Thin Section. The section shows a medium coarse-grained rock with crystals up to 5 mm. in length, though the average is considerably less than this. The rock has been greatly altered but the chief primary minerals would appear to have been augite, labradorite and ilmenite.

The augite has been least altered but it is generally surrounded by a wide rim of tremolite. The plagioclase has been sausseritized and kaolinized and is very difficult to determine. A few small fresh crystals have the composition of labradorite.

Epidote is one of the products of alteration.

Small residual crystals of ilmenite are surrounded by extensive leucoxene.

This rock is classified as Gabbro.

SPECIMEN NO. 27A.

Locality.

300 yards south west of Bald Trig. Station - in north-east of the District.

Description.

Hand Specimen. The hand specimen shows a fine-grained acid rock with a very fine - aphanitic - white groundmass. In this is set atfairly wide spacing crystals of quartz and felspar which are readily visible to the naked eye but very small. A green mineral appears to be arranged in small irregular strings. The field relation is that of an intrusive rock which occurs in several rather small outcrops.

Thin Section. Phenocrysts consist of quartz, which has been generally rounded and embayed, orthoclase and sodic andesine. They average about 0.5 mm. across, are equidimensional and are distributed at random.

The groundmass consists of microscopic crystals, apparently of felspar and quartz. Throughout this and particularly along cracks occur tiny aggregates of chlorite and epidote. The name suggested is Quartz microporphyry.

SPECIMEN NO. 27B:

Locality:

Near Specimen No. 27A.

Description:

Hand Specimen. Rock has a light coloured aphanitic groundmass with small phenocrysts of quartz and felspar to the order of 1 mm. apart.

Thin Section. This section contains mainly quartz phenocrysts, rather smaller than those in Specimen 27A. The quartz is generally broken and rounded by resorption. Occasional phenocrysts of plagioclase and perhaps orthoclase are present. Groundmass is microcrystalline; it is of felspar and quartz with chlorite less prominent than in Specimen No. 27A.

Name of rock suggested is Quartz microporphyry.

SPECIMEN NO. 31.

Locality:

From a knoll in the western part of the area enclosed by the large loop in the Molonglo River and the railway, west of Burbong. Knoll is about 500 yards north of the railway.

Description:

Hand Specimen. Fairly coarsely porphyritic with phenocrysts of felspar and quartz up to 7 mm. in length. The felspar is white and appears to be about equal in amount to the quartz. The groundmass is rather fine and grey-green in colour. The specimen was collected from a rather irregular intrusion some 200 yards wide at this point and extending in an east-west direction for many hundreds of yards. An euhedral crystal of a pink-brown sulphide in the hand specimen is presumably pyrrhotite.

Thin Section. Phenocrysts of quartz are rounded and embayed by resorption which has produced an enclosing ring of micrograpophyric texture, apparently of quartz and felspar (orthoclase ?). Broad irregular twinning of the larger crystals of felspar is common but sections suitable for determination of the composition are rare. It would appear, however, to be a sodic andesine. Kaolinization of the felspar is extensive. Epidote and chlorite are quite common. The mineral from which the chlorite has been formed cannot be determined.

The groundmass is fine and irregular. Granophyric intergrowths make up an appreciable proportion of it. Absence of twinning suggests the felspar is orthoclase. If this is the case the proportion of akalic to calcic felspar is approximately 1 : 1.

Rock can therefore be described as Granophyric Porphyritic Adamellite.

SPECIMEN NO. 32.

Locality:

This specimen was collected from near the eastern margin of the outcrop of porphyry half a mile north of Trig. Station Atkinson.

Description:

Hand Specimen. The rock is dark grey-green in colour, even-grained and doleritic in texture. The grainsize is medium to fine with light and dark mineral sub-equal. Crystals of felspar can be seen. The dark mineral appears chloritic.

Thin Section. The texture is doleritic with laths of plagioclase set around numerous irregular anhedral to subhedral crystals of epidote and chlorite. Occasional crystals of quartz occur in the groundmass.

Magnetite is common. The felspar is andesine. Crystals rarely reach 2 mm. in length and are generally smaller. In view of the proportion of soda in the felspar and the presence of fine quartz the correct name, despite the doleritic texture, is diorite.

SPECIMEN NO. 34.

Locality:

Railway cutting just east of Dairy Station Creek.

Description:

Hand Specimen. Fine-grained, stratified, grey-brown in colour with quartz and white spots of felspar apparent. Looks like a tuff.

Thin Section. Fine matrix, largely of sericite, some of which has become muscovite. Set in this are irregular crystals and aggregates of crystals in lenses. The crystals are largely of quartz, generally less than 0.5 mm. in length. Occasional crystals of andesine also occur.

Name suggested for the rock is Quartz (dacite) tuff.

SPECIMEN NO. 35.

Locality:

In same cutting as No. 34.

Description:

Hand Specimen. It is a light brown bedded rock. Fairly coarse with grains of quartz and felspar set in a fine "flaky" groundmass.

Thin Section. Irregular crystals of quartz with very subordinate felspar are set in a groundmass of sericite and other fine indeterminable minerals. The quartz is very variable in size - from almost microscopic to just under 1 mm. in length. It constitutes about 30 per cent of the total. Its shape and outline are very irregular and the grains are often fractured. Strain shadows are very noticeable. The felspar is sodic andesine which occurs in irregular crystals much smaller than the average quartz. It is very subordinate. Some muscovite has developed. A single small crystal of zircon was noticed, suggesting that detritol sediments are included in the rock. It is thus an impure sheared quartz (dacite) tuff.

SPECIMEN NO. 36.

Locality.

As for Nos. 34 and 35.

Description.

Hand Specimen. A fine light brown rock which appears to have been slightly sheared. Grain size is too small for the grains to be seen with the naked eye. Obviously it is sedimentary or pyroclastic.

Thin Section. It is essentially similar to Specimen No. 35 but finer. The proportion of quartz to matrix is lower and crystals are smaller. Felspar is perhaps even more subordinate. The groundmass is very noticeably felted and orientated in bedding planes. Strong limonite staining has occurred. The quartz is fractured. Shearing is evident with the development of tiny quartz veinlets and lenses, probably in the direction of shear.

The rock is a sheared Quartz tuff.

SPECIMEN NO. 42.

Locality:

On east boundary of the district, 300 yards north of the Bungendore road.

Description:

Hand Specimen. The hand specimen is of a rather fine green rock. The texture is even and grain boundaries are not well defined. The rock occurs in the field adjacent to the gabbro (Specimen No. 26) suggesting a genetic relationship. Disseminated throughout are small sparse irregular clusters of a pink brown sulphide, presumably pyrrhotite.

Thin Section. The texture is doleritic. Laths of felspar surround irregular crystals of ferromagnesians generally not exceeding 2 mm. in length. The light and dark minerals are approximately equal in amount. Alteration of the ferromagnesians has been extensive. A few unimportant crystals of augite are apparently unaltered remnants. The alteration products are tremolite (which forms the bulk of the dark minerals), chlorite and epidote or zoisite. Some apatite is present, also small scattered irregular crystals of magnetite or ilmenite and pyrrhotite.

The rock is Dolerite.

SPECIMEN NO. 55.

Locality.

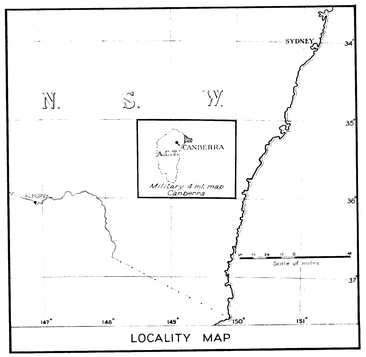
This specimen was collected from one of a number of boulders which occur due North of the trigometrical station Sparrow at a distance of about half amile north of the Bungendore road.

Description.

Hand Specimen. The rock is grey-white and porphyritic with a very fine groundmass which is apparently largely of quartz. Medium sized phenocrysts of felspar and quartz can be seen, also a very subordinate green mineral. The quartz grains are strongly stretched and planes of shearing can be discerned, particularly in the weathered portions where the rock is pink to brown.

Thin Section. The texture is strongly porphyritic with phenocrysts of quartz and felspar up to 3 mm. in length. The groundmass, also of quartz and felspar, is very fine but glass appears to be absent. The groundmass shows a marked flow pattern in the direction in which the elongate phenocrysts are orientated. The quartz is very strongly strained. It is frequently cracked and marginally resorbed. Strings of a dark mineral follow the flow and lie round the periphyry of phenocrysts The mineral appears to be leucoxenized ilmenite. Associated with it is some chlorite. The felspar is basic oligoclase or sodic andesine.

The rock may be called a sheared Granodiorite porphyry.



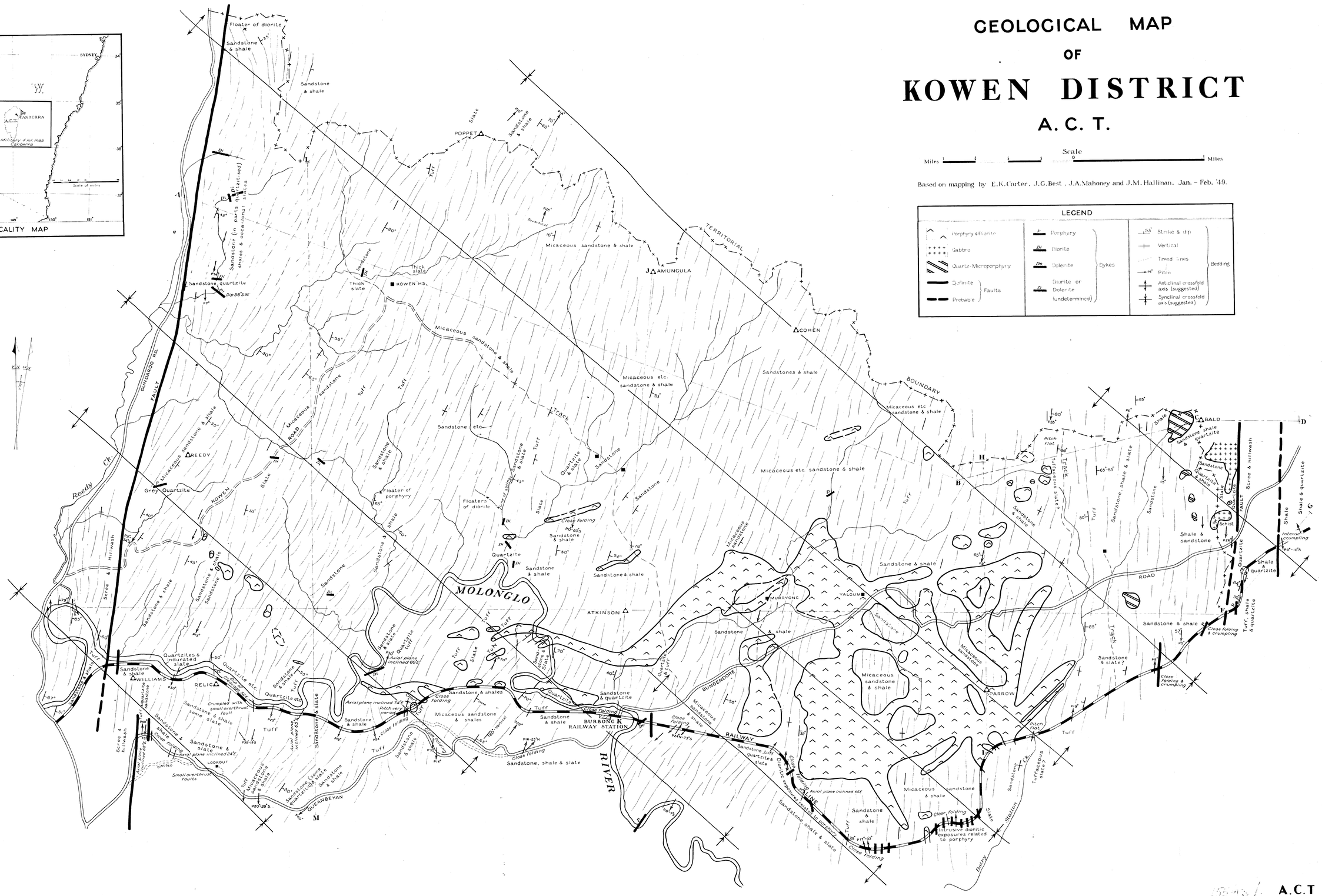


PLATE I

GEOLOGICAL MAP
OF
KOWEN DISTRICT
A. C. T.

Based on mapping by E.K.Carter, J.G.Best, J.A.Mahoney and J.M.Hallinan. Jan. – Feb. '49.

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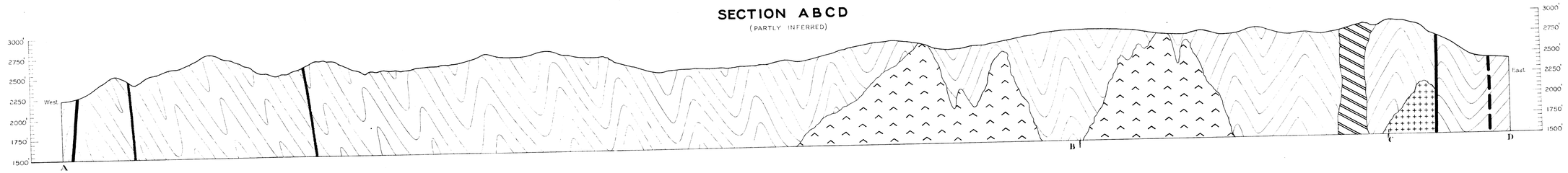
A.C.T 5-1
J.A.B.

SECTION ABCD

(PARTLY INFERRED)



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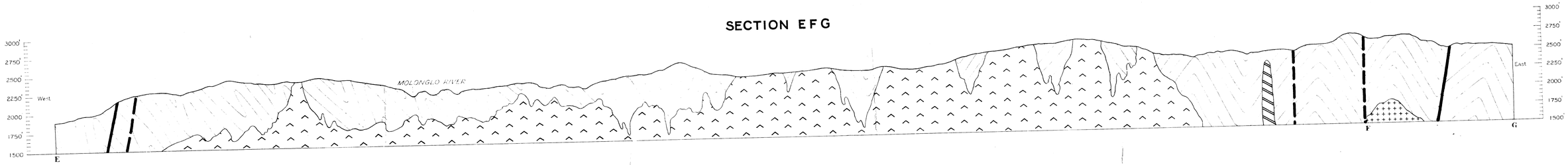

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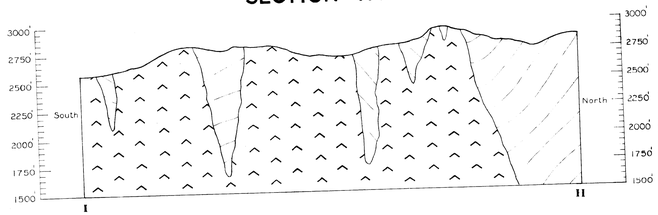

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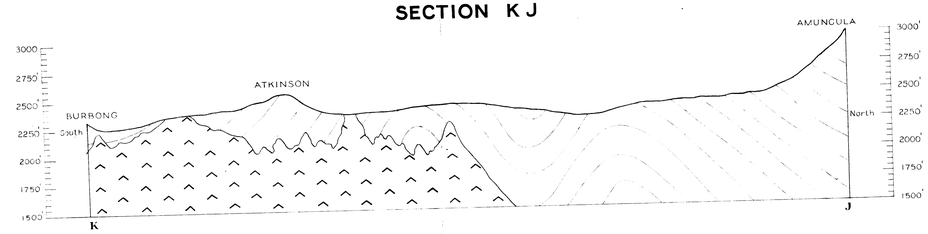

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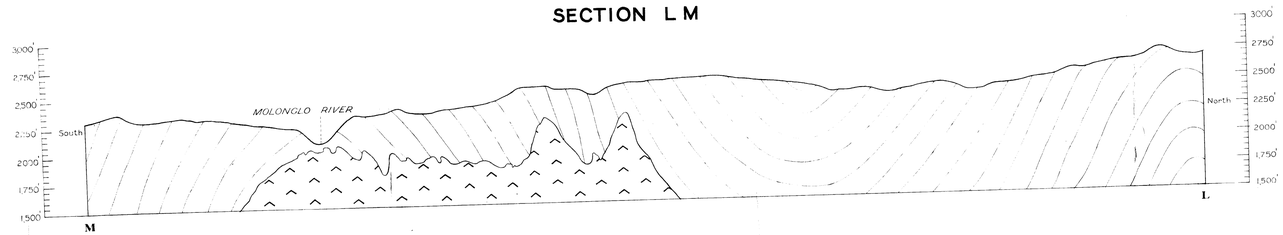

GEOLOGICAL SECTIONS

OF

KOWEN DISTRICT

A. C. T.

(SEE PLATE 1)

Horizontal Scale

Miles 1 ½ 0 ½ 1 Miles

Vertical Scale

Feet 500 0 500 1000 1500 2000 2500 3000 3500 Feet

Note: Detail of folding shown on sections partly diagrammatic
Topography based on Canberra Ordnance Map. Scale 1 inch to 1 mile

ACT 5-2
J.A.B.

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